temal force, and the distance GS of this axis from the centre

*∕"P'1^*

of gravity is = <— (see Rotation, No. 96.), and it is

M-Gç

taken on the opposite side of G from *q,* that is, S and *q* are on opposite sides of G.

Let us express the external force by the symbol F. It is equivalent to a certain number of pounds, being the pres­sure of the wind moving with the velocity V and inclination *a* on the surface of the sail D ; and may therefore be com­puted either by the theoretical or experimental law of ob­lique impulses. Having obtained this, we can ascertain the angular velocity of the rotation and the absolute velocity of any given point of the ship by means of the theorems es­tablished in the article RotatioN.

But before we proceed to this investigation, we shall con­sider the action of the rudder, which operates precisely in the same manner. Let the ship AB (fig. 11), have her rudder in the position AD,

the helm being hard a-

starboard, while the ship

sailing on the starboard

tack, and making leeway,

keeps on the course *a lt.*

The lee surface of the rud­

der meets the water ob­

liquely. The very foot of

the rudder meets it in the direction DE parallel to *a b.* The parts farther up meet it with various obliquities, and with various velocities, as it glides round the bottom of the ship and falls into the wake. It is absolutely impossible to cal­culate the accumulated impulse. We shall not be far mis­taken in the deflection of each contiguous filament, as it quits the bottom and glides along the rudder ; but we nei­ther know the velocity of these filaments, nor the deflection and velocity of the filaments gliding without them. We therefore imagine that all computations on this subject are in vain. But it is enough for our purpose that we know the direction of the absolute pressure which they exert on its surface. It is in the direction D*d*, perpendicular to that surface. We also may be confident that this pressure is very considerable, in proportion to the action of the water on the ship’s bows, or of the wind on the sails ; and we may suppose it to be nearly in the proportion of the square of the velocity of the ship in her course ; but we cannot affirm it to be accurately in that proportion, for reasons that will readily occur to one who considers the way in which the water falls in behind the ship.

It is observed, however, that a fine sailer always steers well, and that all movements by means of the rudder are per­formed with great rapidity when the velocity of the ship is great. We shall see by and by, that the speed with which the ship performs the angular movements is in the propor­tion of her progressive velocity : For we shall see that the squares of the times of performing the evolution are as the impulses inversely, which are as the squares of the veloci­ties. There is perhaps no force which acts on a ship that can be more accurately determined by experiment than this. Let the ship ride in a stream or tideway whose velocity is accurately measured ; and let her ride from two moorings, so that her bow may be a fixed point. Let a small tow line be laid out from her stern or quarter at right angles to the keel, and connected with some apparatus fitted up on shore or on board another ship, by which the strain on it may be accurately measured ; a person conversant with mechanics will see many ways in which this can be done. Perhaps the following may be as good as any ; let the end of the tow-line be fixed to some point as high out of the water as the point of the ship from which it is given out, and let this be very high. Let a block with a hook be on the rope, and

a considerable weight hung on this hook. Things being thus prepared, put down the helm to a certain angle, so as to cause the ship to sheer off from the point to which the far end of the tow-line is attached. This will stretch the rope, and raise the weight out of the water. Now heave upon the rope, to bring the ship back again to her former position, with her keel in the direction of the stream. When this position is attained, note carefully the form of the rope, that is, the angle which its two parts make with the horizon. Call this angle *a.* Every person acquainted with these subjects knows that the horizontal strain is equal to half the weight multiplied by the cotangent of *a, or* that 2 is to the cotangent of *a* as the weight to the horizontal strain. Now it is this strain which balances and therefore measures the action of the rudder, or D*e* in fig. 11. Therefore, to have the absolute impulse D*d* we must increase De in the pro­portion of radius to the secant of the angle *b,* which the rudder makes with the keel. In a great ship sailing six miles in an hour, the impulse on the rudder inclined 30° to the keel is not less than 3000 pounds. The surface of the rudder of such a ship contains near 80 square feet. It is not, however, very necessary to know this absolute impulse *Dd* because it is its parts De alone which measures the energy of the rudder in producing a conversion. Such experi­ments, made with various positions of the rudder, will give its energies corresponding to these positions, and will settle that long disputed point, which is the best position for turn­ing a ship. On the hypothesis that the impulsions of fluids are in the duplicate ratio of the sines of incidence, there can be no doubt that it should make an angle of 54° 44' with the keel. But the form of a large ship will not admit of this, because a tiller of a length sufficient for managing the rudder in sailing with great velocity has not room to deviate above 30° from the direction of the keel ;@@1 and in this posi­tion of the rudder the mean obliquity of the filaments of wa­ter to its surface cannot exceed 40° or 45°. A greater angle would not be of much service, for it is never for want of a proper obliquity that the rudder fails of producing a con­version.

A ship misses stays in rough weather for want of a suffi­cient progressive velocity, and because her bows are beat off by the waves ; and there is seldom any difficulty in wear­ing the ship, if she has any progressive motion. It is, how­ever, always desirable to give the rudder as much influence as possible. Its surface should be enlarged (especially be­low) as much as can be done consistently with its strength, and with the power of the steersman to manage it ; and it should be put in the most favourable situation for the water to get at it with great velocity ; and it should be placed as far from the axis of the ship’s motion as possible. These points are obtained by making the sterb-post very upright, as has always been done in the French dockyards. The British ships have a much greater rake ; but our builders are gradually adopting the French forms, experience having taught us that their ships, when in our possession, are much more obedient to the helm than our own.—In order to as­certain the motion produced by the action of the rudder, draw from the centre of gravity a line *Gq* perpendicular to D*d*, (D*d* being drawn through the centre of effort of the rudder). Then, as in the consideration of the action of the sails, we may conceive the line *q*G as a lever connected with the ship, and impelled by a force D*d* acting perpendicularly at *q.* The consequence of this will be, an incipient conver­sion of the ship about a vertical axis passing through some point S in the line *q*G*,* lying on the other side of G from *q;*

*J∙p∙P*

and we have, as in the former case, GS=

Thus the action and effects of the sails and of the rudder are perfectly similar, and are to be considered in the same manner. We see that the action of the rudder, though of

@@@, In modern ships the improvements in the tillers will admit of the rudder's being put over so as to make an angle of 54° 44’ with the keel—the angle of maximum advantage assigned to it by theory.